CHAPTER – II

LITERATURE REVIEW

2.1 INTRODUCTION

Results of any research can be useful only, particularly in area of application research such as technology, when relevant previous literature on it is reviewed and analyzed. This chapter is an attempt to record in brief what has been reported in the research literature on (new) technology adoption, adaptation and technological capability building in production industry worldwide from flexible management point of view.

The literature reported has been organized into the following broad headings:

- Technology
- Technology management
- Flexibility
- Technology adoption
- Technology adaptation
- Technological capability building

2.2 TECHNOLOGY

Technology means the systematic application of scientific or other organized knowledge to practical task. There are a number of definitions in existence for Engineering Technology, most of which relate to manufacturing and product development industries (Hornbeck, 1999). Martino (1983) defined technology as the totality of means employed to provide objects necessary for human sustainability and comfort. Zhao and Reisman (1992) stated that the concept of technology can be defined with respect to a context and provides a definition of technology with reference to economics, sociology, anthropology, management etc. In a broad sense, technology denotes the broad area of purposeful application of the contents of the physical life and behavioral sciences. It comprises the entire notion of techniques as well as the medical, agricultural, management, and other fields with their total hardware and software contents. Beets (1994) provided a similar definition and stated that while science is a general approach to understanding nature,
technology is a generic way of providing a functional capacity of doing things. Technicist definition of technology was offered by Gibson (1976) when he stated, “technology is considered to be scientific, engineering and managerial knowledge which makes possible the conception, design, development, production, and distribution of goods and services.” As a matter of fact, it is a good description only of industrial technology, and thus, a specific example of man's knowledge, which is necessary for the satisfaction of some of his wants. Gruber and Marquis (1969) defined technology as "the means of capacity to perform a particular activity.” It is derivable from this definition that technology involves process in the sense that it is a human's capability to transform physical objects. This definition on the other hand seems to be so broad as to encompass almost every sphere of human activity. It is also vague in a sense that it does not shed much light on what the ‘means’ or ‘capacity’ for undertaking a given activity might be. Technology can be defined broadly and also narrowly. An all-embracing definition of technology is ‘technology means the systematic application of scientific or other organized knowledge to practical task.’ Broadly speaking, technology is purposeful application of knowledge developed in various areas. It is clear from the above-mentioned definitions that the concept of technology has been classified by different criteria into categories that include hardware or software; general or firm specific; and alternative, intermediate or appropriate.

Technology has the capability of providing significant competitive advantage. However it cannot be viewed in isolation and an integrated approach in the delivery of a product, process or service to a customer is absolutely necessary if real competitive advantage through customer satisfaction is to be both obtained and sustained (Vandeth, 1991). Technology comes with mixed blessings. It considerably enhances human muscular and mental capabilities, and conditions our living surroundings to make it more and more comfortable. The role of technology has been the most crucial in the overall growth and development of a country (Sharif, 1989).

Technology crosses borders in the form of scientific papers, foreign sponsorship of university research, international licensing, cross-border equity stakes in hi-tech start-ups, and international academic conferences. Tapping into the global market for technology is a potentially important source of resource leverage (Hamel and Prahalad, 1993). To go global, a firm has to be strong in technology and market locally. Technology and markets are made global by customer needs. According to Ohmae (1989) globalization is required
because customer needs have been globalized and fixed cost of meeting such needs have soared high.

Technology addresses the application of scientific and engineering knowledge to the solution of problems while technology management has a broader charter: the integration of technology throughout the organization as a source of sustainable competitive advantage. It has been indicated that the changing dynamics of technology management can be best seen as an evolving technology paradigm for competitive advantage (Werther et al. 1994).

2.2.1 Requirements of new technology

The nature and structure of a high technology firm is reflected directly from the environment the firm is operating in and the characteristics of the technology it is dealing in (Moharman and Glinow, 1990). The shrinking technology life cycles are putting pressures on firms for quick commercialization of innovations. This presses the organization from two opposite sides. On the one hand, it requires a firm to use high technology as tools, and on the other hand, it produces high technology as their products. Certain characteristics of the technology itself have strong bearing on organization of hi-tech firms. The interdependence of individuals in research and development has been very well appreciated. The authors have discussed the various environmental factors and their effects on the organizational restructuring with special reference to organizations as learning systems, the use of flexible and temporary designs, integration, permeable boundaries, differentiation, and ongoing resolution of competing tensions. Effective high technology organizations are able to deal with many conflicting demands using the appropriate measure(s) proposed. Nevis et al. (1995) have emphasized that organizations dealing in hi-tech products must visualize themselves as learning systems if they wish to remain ahead of competitors in global business.

Analyses of R&D performance focuses on contributions made in enhancing capabilities and quality of existing products and processes, development of products and processes yielding major commercial advantages over competition, and advances in the knowledge to cope up with the future challenges (Gold, 1989). He emphasized that R&D should generate three additional kinds of improvements which are reducing or minimizing increase in cost of producing existing products, reducing lags behind competitors’ innovation in products and processes, and adapting designs and processes to shifts in supply and prices input. The top management is considered very important and
responsible for R&D improvement and a broad framework has been provided for performance evaluation of R&D programs. Sushil (1990) has presented a concept of ‘wastivity’ which can be made use of in evaluating the R&D performance particularly in minimizing the waste.

The need for creative research for Japan to sustain its global leadership in hi-tech products, has been emphasized by Jun’ichi (1987). After the World War II when Japan needed to establish itself in the world market, started manufacturing inexpensive high-quality goods which helped it in spreading the benefits of modern science and technology around the world. Most of these products were based on the researches conducted in the technologically advanced countries. Japanese manufacturers responded to oil crisis of 1970s very intelligently by automating production to reduce labor cost and offsetting higher fuel bills. The other alternative could be to reduce the head counts which could lead to higher unemployment and de-industrialization of Japan. He also discussed the number of technological breakthroughs realized and commercialized in Japan. A wide gap in the two, shows Japan’s weakness in creative research and to overcome this, the author has strongly pleaded the candidature of Japanese universities as a breeding ground for basic researches and inspired researchers.

2.2.2 Impact of new technology

New technology can have different levels of impact depending on their pervasiveness and the structure of organization and society (Rao, 1994). Technology and social change are inter-dependent. The steam locomotive and industrial revolution brought about significant changes in life style and working pattern. Likewise informatization and knowledge intensification in the high tech era are bringing forth some fundamental shifts in values. For example, in agricultural society the wealth used to be decided by agricultural production, while production of agricultural products continued to be a necessity in the industrial age, their abundance is not necessarily a symbol of wealth (Subramanian, 1990).

Choi (1993) has suggested that science and technology are not just one aspect of growth, but a vital factor in socio-economic development particularly among less developed countries. It is this technological revolution that less developed countries would need to harness as an instrument of growth and socio-economic development.
In recent years, in recognition of the pivotal role of new technology in the development process, increasing attention has been directed to the formulation and implementation of technology policies in less developed countries.

Preamble to the National Technology Policy for America 1992, stated that America's economic performance and international (business) influence rest in large part, on its technology base. New technology has accounted for the bulk of US productivity gains during past, spawned entire new industries, created millions of jobs. It has been a primary source of America's ability to get business and maintain a high standard of living for its citizens.

Transfer of technology is important for competition if it significantly improves a firm's competitive advantage or industry structure. Competitiveness has been considered the key issue to economic success and future prosperity in this new globalized economic reality (Barbosa, 1997).

Government can play a vital role in the process of technology transfer. Governments must make money available for research and development and support the local investors who participate in the process of technology transfer. The government regulations need to be conducive on transfer of technology. From active support in the form of subsidies, tax benefits and more indirect methods, government regulations have a significant influence on the economic benefits of technological transformation.

2.3 TECHNOLOGY MANAGEMENT

Twenty-first century is going to be totally dominated by technology and technological competitiveness. The entire world will agree to the fact that the atmosphere for creative application of technology is critical to the economic growth, national security, and social stability (Ramo, 1989).

Technology and its management cannot be narrowly viewed merely in terms of machines, equipment, instruments and processes. Manufacturing technology comprises five interconnected and interdependent facets. Each of these facets need to be recognized explicitly both individually and in terms of its multilateral linkages with others, for the purpose of managing technology effectively. These facets are:

(i) Production Processes: This facet includes design and layout of production facilities; type and mix of machines and equipment; flow of information, materials and people;
elements of automation, computer systems and hardware, monitoring, control, maintenance and simulation of operations and facilities.

(ii) **Product and Process Design:** This facet is related with the design of products including materials, parts, components and features, on one hand, and design of processes and their interconnection with products, on the other. Both products and processes may be designed simultaneously in terms of concurrent engineering towards achieving zero defect production.

(iii) **Information Systems:** This facet includes methods and systems for communication, integration, intelligence, production control and overall coordination.

(iv) **Orgaware Technology:** This facet relates to organizational support system that facilitates the transformation process, including administration, communication, integration, coordination, learning, acquisition and retention of knowledge and information and incentive/reward system.

(v) **Material Technology:** This facet relates to the knowledge and use of the properties and attributes of core materials, interconnection of parts, composites and functions.

Production/manufacturing technology, in the holistic sense, describes the way in which the foregoing five facets interact together to convert resources into outputs. Effective management of technology implies continuous improvement, consistency and coordination of all the foregoing five facets. The emphasis is on bringing about continuing and combined improvements in order to sustain and upgrade the company's distinctive competency towards its potential competitive advantage.

Bahouth (1994) has discussed the necessity of exposing future managers to technology management, and identified areas of technology management these future managers should be exposed to. He argued that technology is the major factor behind productivity improvement and the rising standard of living. For some organizations, setting policies regarding the technologies which have an impact on their operations is the same as developing their strategies. Universities are supposed to be the training fields where managers are prepared for future business battles. A few universities, realizing the impact of technology on profitability, have offered business courses in technology management. The increasing importance of technology management in the modern age was discussed by Cyret and Kumar (1994). They discussed the possible applications and problems that can be encountered in its industrial applications.
Orr and Sohal (1999), in their study based on interviews conducted with four German multinationals, have discussed issues of technology management in the context of global manufacturing. Based on observations, they have identified three common strategies/practices adopted by the companies studied namely: maintaining focus on core competencies/technological capabilities; maintaining a continuing dialogue between the R&D function at the headquarters and the overseas operating units; and providing extensive duration and training for all employees. Amin (2000) found that from a viewpoint of strategic research and development, there are many scientific and technological challenges posed by the lack of a unified mathematical framework. Genus and Kaplani (2002) have addressed the synergy between operations, technology management and human resource management by way of a study of operational innovation in firms.

Husain et al. (2002) have conducted a study to analyze technology management practices of firms in the automobile industry in India. The situation-actor-process-learning-action-performance (SAP-LAP) paradigm was used to analyze the cases.

Riccaboni and Pammolli (2003) have analyzed the relationships between technological regimes, regimes of local interaction, and the global structure of an industrial network. Bhardwaj and Sharma (2005) have conducted a filed study, and reviewed the relevant literature and synthesized issues concerning technology acquisition and technology transfer, as applicable to the automotive industry in particular.

Davies and Ko (2006) have studied and tested the hypothesis that companies, who move away from the traditional Hong Kong business model by adopting up-grading strategies, enjoy superior performance. The broader implication was that Hong Kong manufacturing firms began to escape the iron fetters of a business model originally imposed on them. Mora-Monge et al. (2007) have investigated the issue of strategic fit between Advanced Manufacturing Technologies (AMT) and its impact on performance in less developed countries. Narain et al. (2007) reviewed a wide range on literature on the justification of AMT. Bosco (2007) has presented a technology picture of the Lombardy region of France and the main policy actions undertaken in recent years in that region to promote a nest of linkages within actors, moving along the approach of regional innovation system. The evolution of Lombardy’s economic structure and international position led the regional government to build up a network of public and private stakeholders in the effort of promoting the creation of new knowledge and supporting innovation at local level.
Narvekar and Jain (2006) have developed a framework to understand technological innovation process by introducing constructs to account for the complexity and the uncertainty in the innovation process.

2.3.1 Technology management - operational issues

Management of technology as seen by Asian managers and scientific and educational professionals involves new approaches to developing and managing the human resources, team development and profit sharing while European and other believe in development of an organization structure to handle the issues of coordination, conflicts and collective decision-making alongwith human resource development (Swierczek, 1991).

Change in basic conception of managerial responsibilities is required for improving international competitiveness of technology based firms. The emphasis on narrow specialization of managers within each major functional area delivered results only in restricted domain. Effective integration of specialized functions at successively higher corporate levels, as demonstrated by Japanese in last two decades, is a worth following strategy to improve competitiveness in global market. Making technological contribution to the competitiveness visible, requires reaching beyond R&D and engineering criteria and needs to take internal and external environmental factors into consideration (Gold, 1992).

The CEO’s interest in technology management is of paramount importance in bringing a change in the attitude towards the management of technology function (Mathis, 1992). The role of technology managers differs from that of the R&D managers. An R&D manager uses the firm’s internal resources to develop technologies that a firm needs to achieve its corporate objectives while the technology manager sees to it that the firm has the technology available to it and uses effectively in all spheres of application. The technology manager forecasts, plans, acquires, develops, and assesses the technology which the firm is using and even takes decisions related to phasing out the same (Mathis, 1992).

The transition to a radically new technology can have a significant and possibly disruptive effect on the work force. Process documentation acts as a basis for internal capability development. Staffing choices concerning the acquisition of capabilities have been explored by Chmelewski and Bilger (1998). The understanding of the need for change in the attitude has to be supplemented with technological forecasting and strategic planning to expedite the change.
Faced with competition from new technologies and rapid introductions of new products by their competitors, leading companies are beginning to focus on improving technology management, the link between product strategy and product development. It has been reviewed by Anders (1999) that companies can achieve significant R&D performance improvements by implementing the technology management best practices used by leading companies to manage the development and implementation of new technologies.

A framework has been developed by Bowonder and Miyake (2000) for analyzing technology management issues by combining the knowledge management concepts and ecosystem theory concepts. According to them, technology strategy can be conceptualized as a process of aligning knowledge search, knowledge envisioning, knowledge creation and knowledge evolution with a view to meeting changing customer needs, competitive threats and the future technology trajectory. Da Silveira (2002) has discussed the concept, process and content issues with regard to improvements in operations and technology management (TM). He introduced a framework for the analysis of improvement trajectories (ITs) in operations and TM, by defining the concept of ITs, grounding on the evolutionary economic issues of path dependence and dynamic capabilities. He reviewed and integrated seven dimensions of the process and content of ITs into a research framework. He further build research propositions to base further research and finally, discussed the roles of implementation history, innovation capabilities, and strategic orientation as determinants of IT success.

A few critical success factors in technology management have been pointed out by Metzemackers (2000). These are: intuition, team-searching and building for a lean and mean supply chain, and the logistic technology that spots the right component suppliers in good time and organizes the system creation process reliably, fast and cost effectively.

An integrative framework covering knowledge enhancement, facilitation and training has been adopted by Government of India to derive benefits both in the short as well as in the long term. Wide-ranging activities have been undertaken in close inter-action with industry, research organizations, technical/management institutes, consultants and others (Kumar and Bhat, 2000).

The growing implications of technological change on society and the dependencies of private and public interests call for a holistic approach to technology management. Based on a systems approach, Tschirky et al. (2000) has developed a framework which helps analyze and contrast technology management on a company and national level. The
overall process of technology management has been divided into different phases by the different researchers and accordingly the related issues have been addressed. These phases are, forecasting and planning, development/acquisition, transfer, adoption and adaptation, diffusion and substitution, utilization, and phasing out.

Gupta (2001) has used a moderated, regression model and data in his study from a few manufacturing industries to examine the advanced manufacturing strategy based on organizational size. He concluded that high technology has a negative effect on to the size of an organization. This study also revealed that, contrary to some previous research, large and small firms respond differently to technological changes.

Gomes (2004) has distinguished between two concepts of technology: a theoretical level of technology (that is, a technology possibilities frontier) and a level of technology in practice (that is, ready to use in production technology). Having these two concepts in mind, he developed an inter-temporal optimization model in which it may be possible to control the theoretical knowledge frontier. The result was an endogenous growth model where long run growth depended on the technology choices made by a social planner.

Based on a quantitative survey in combination with case studies of two Chinese chemical enterprises, Cheng and Bennett’s (2007) study concluded that in this industry, building competences is more effective than privatization and restructuring to improve performance. The chemical industry in China is facing fierce competition and exposure to market forces as a result of changes in the country’s economic policy. The Chinese government has applied administrative actions rather than simply relying on market forces to address the changing dynamics. It has attempted to privatize state-owned chemical enterprises by corporatization, coupled with industrial restructuring by merging individual state-owned enterprises into groups.

2.3.2 Need of technology transfer

Transfer of technology from developed countries to less developed countries is a mutual necessity (Habibie, 1990). Unfortunately, this perception is not held widely across the globe. The low-income population of the world can become the technology leaders and donors of technology only if income and purchasing power rise. This is likely to happen only with the real increase of productivity of the facilities and quality of their produce. Dependence on natural resources also cannot take a country far ahead, and this has been proved in case of Japan and Korea. The interest of the developed countries, of course, lies in expanding markets for their products.
Technology gap is a reality everywhere. The technology transfer, therefore, becomes imperative in order to bridge the gap. The process of technology diffusion is not transferring shelf knowledge from affluent to poor economies. Perhaps dispatching technologies to third world countries is an act of sale rather than one of technology transfer. Evidently, the international market of technology is an imperfect one as buyers are not adequately informed about the product and they are easily influenced by the potential seller (Banerjee, 1990). Saji et al. (2005) have identified the various levels and directions of transferor transferee relationship, and the relationship variables that would determine such a relationship for effective technology transfer in the context of international joint ventures. Nations like Japan and Korea and other newly industrialized countries have decided not to continue re-inventing the wheel by indigenous development of technologies as a means of ensuring improved standards of living. The only solution was to replace so called self reliance and self development by technology transfer through cooperation, and enabling training of young and brilliant scientists and engineers abroad, employment of foreign experts and technicians, and vigorous transfer of appropriate and proven technologies for their adaptation, absorption and eventually further development.

A framework for technology transfer from developed countries to less developed and least developed ones has been proposed by Madu (1989). He has covered a wide variety of topics including relevant technology for a country, the nature of technology, evaluation of indigenous technologies and process of technology transfer.

2.4 CONCEPT OF FLEXIBILITY

Managers recognize and accept that the flexibility is used in two senses; range and response. Differentiating between range and response flexibility helps them to articulate their flexibility needs. They do understand that the response flexibility is more important than range flexibility. They see flexibility as a means to other end and not as an end in itself. The variety and dimensions of flexibility, which mostly concern them are determined by variety and uncertainty (Slack, 1986).

Achieving benefits of flexibility in practice depend on successfully resolving a number of issues, like technical, economic, and organizational. A number of measures which the company must adapt while incorporating flexibility, have been suggested by Bessant and Heywood (1986).
The range of flexibility with concepts of sensitivity and stability has also been characterized. Sensitivity refers to the degree of change tolerated before a deterioration in performance takes place. Stability relates to the size of each disturbance for which it can meet the performance levels expected of it. In other words, while sensitivity determines whether or not a response is needed, stability determines whether or not a system is capable of responding, given that a response is needed. In addition, stability also determines the range of magnitude of changes within which the feasible responses occur. In general, reduced sensitivity and greater stability imply increased flexibility (Gupta and Buzzacott, 1989).

Flexibility can be used for both offensive and defensive strategic purposes. An offensive strategic user is proactive in that he/she uses flexibility to continually change his/her environment whereas a defensive strategic user is reactive in that he/she attempts to react to such changes (Swamidass, 1987).

2.4.1 Measuring flexibility

The value of flexibility is the difference between expected profits achieved through a flexible and inflexible system. When the value of flexibility is high for a firm, it implies that firm’s flexibility is low as compared with the levels suitable for the environment that the firm operates in. On the other hand, if the value of the flexibility is low, the flexibility of the firm is judged to be high in relation to its needs. The value of flexibility depends on such factors as the relative frequency of occurrence of different changes that the system is required to cope with, the utility of reduced impact of changes, and the physical properties of the system. Hence, the value of flexibility for the same system may vary depending on the frequency, the type and importance of changes the flexible system is required to cope with (Gupta and Buzacott, 1989).

Total system flexibility measure is the weighted combination of two factors; the quickness of response to change, and the economical response to a change factor. However, such measurements can serve, at best, only as conceptual construct for showing nature and importance of both factors (Chung and Chen, 1990).

The manufacturing system flexibility can be measured by two factors; the speed at which there is a response to change, and the economical impact of the response to change. Quickness, being an attribute, can be evaluated as the lead time between a customer’s order receipt and the completion of the product. For a quick response to change, the lead times must be minimised (Masuyama, 1983). Two measures of flexibility, application
flexibility and adaptation flexibility have been suggested by Zelenovic (1982). He has defined application flexibility as the value of design adequacy. Design adequacy is the probability that the given structure of a production system will adapt itself to environmental conditions and to the process requirements, within the limits of the given design parameters. Adaptation flexibility is defined as the amount of time needed for the system to adapt to a changed situation.

Various flexibility measures have been categorized into six types of approaches; economic consequence based approach, performance based approach, multi-dimensional approach, petri-net approach, information theoretic approach, and decision theoretic approach (Gupta and Goyal, 1989). Inter-relationships between different types of flexibility have been explored by Rao and Mohanty (1991). They provide a hierarchical approach to the concept of flexibility for assessing the broad flexibility needs of the organization. For this, flexibility have been classified as strategic, tactical, and operational. They also have suggested a framework for measuring flexibility.

Factor analysis has been applied by Dixon (1992) to measure three dimensions of flexibility namely mix flexibility, new product flexibility and modification flexibility. To assess mix flexibility, information has been sought on average number of different product characteristics manufactured during a month, and average number of change-over between these characteristics. To assess new product flexibility, he has collected data on number of samples manufactured and number of new products introduced. For assessing modification flexibility, information has been collected on various aspects related to product that were changed to satisfy customer needs.

2.4.2 Systemic flexibility

The concept of systemic flexibility has been presented by Sushil (1994). According to him, the flexibility in the systemic sense cannot be generated by attaching ourselves to a point on the continuum. The flexibility is generated in the system by virtue of the existence of the continuum. The success lies in making a dynamic balance between the polar extremes. Thus, systemic flexibility is the exercise of the free will or freedom of choice on the continuum to synthesize the dynamic interplay of thesis and antithesis in an interactive and innovative manner, capturing the ambiguity in systems, and expanding the continuum with little penalty in time and efforts. Such a systemic concept of flexibility will have major attributes of spectral, integrative, interactive, innovative and fuzziness character.
Based on that, a flexible system methodology has been developed by Sushil (1997b) which acts as a research methodology for flexible systems management. This methodology tries to resolve the end of continuum paradoxes, by treating all the system based methodologies and techniques as lying on a continuum ranging from hard to soft, and all the problem situations also on a continuum ranging from well structured to unstructured. The three basic components that define dynamic interplay of reality in flexible systems management paradigm are situation, actor and process. They interact flexibly on multiple planes in the ambiguous reality and ultimately melt together into one at the enlightened stage. The boundaries between the three basic components are fuzzy. The engineering enterprise, which is the actor under consideration, forms a part of the situation as well as the process. These three are parts of an inseparable whole. The management in this paradigm can be explained from the point of view of either the situation, or actor, or process. The situation is to be managed to an organic order by an actor through a flexibly evolved self-organizing management process which recreates the situation. The actor understands the ambiguous situation through deep involvement, thinking of general qualitative patterns through reasoning by analogy and exercises the freedom of choice to flexibly and systemically evolve a management process on the continuum in an interactive and innovative manner for generating an organic order in its own reality. The process is a flexible and self-organizing system of management that is to be evolved by an actor using its internal and external flexibility for managing situation in ambiguous and dynamic reality, which mutually influences the process and the actor.

### 2.4.3 Technology flexibility

Technology flexibility is the technology characteristic that allows or enables adjustments and other changes to the business process. Technology flexibility has two dimensions, structural and process flexibility, encompassing both the actual technology application and the people and processes that support it. The flexibility of technology that supports business processes can greatly influence the organization's capacity for change. Existing technology can present opportunities for or barriers to business process flexibility through structural characteristics such as language, platform, and design. Technology can also indirectly affect flexibility through the relationship between the technology maintenance organization and the business process owners, change request processing, and other response characteristics. These indirect effects reflect a more organizational perspective of flexibility. The question of ‘technology flexibility’ has been addressed by developing
and validating a measurement model of technology flexibility. Constructs and definitions of technology flexibility were developed by examining the concept of flexibility in other disciplines, and the demands imposed on technology by business processes. The purpose of building a measurement model was to show validity for the constructs of technology flexibility. The paper has discussed the theory of technology flexibility, developed constructs and determinants of this phenomenon, and proposed a methodology for the validation and study of the flexibility of emerging technologies (Nelson et al., 1997).

The paradigm of manufacturing flexibility has been extended to technology management by Wadhwa and Rao (2000). The potential for design flexibility and its judicious integration with the manufacturing flexibility has been discussed. A conceptual framework involving a dynamic control of structural, process and resource flexibility has been presented and its implications for the Indian context have been discussed. A judicious use of information technology has been suggested to benefit from design flexibility.

### 2.5 TECHNOLOGY ADOPTION

Adoption, the first stage of the technology transfer process, is simply a firm's awareness of a certain technology's existence and the firm's initial pursuit of that technology (Steensma, 1996). Adoption decision refers to the processes by which a new piece of technology is selected for the organization. While the adoption decision clearly affects implementation, it is composed of different processes and is analytically distinct from implementation (Goodman and Griffith, 1991).

Duck (1993) described the need to take people into confidence while introducing any kind of change including the technological changes. He has emphasized the change paradoxes and agreed that trust is hardest to develop and achieve when one needs it most during the change process. Understanding the nature and variety of agendas, which preoccupy potential technology adopters, is arguably a significant form of knowledge for both product developers and, in a wider context, policy makers (Clark et al., 2000).

Hall and Khan (2002) have discussed the concepts of technology adoption, technological standards, and overviewed the contribution of new technology to economic growth. They argued that economic growth can only be realized when and if the new technology is widely diffused and used. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of
the uncertain benefits of the new invention with the uncertain costs of adopting it. An understanding of the factors affecting this choice is essential both for economists studying the determinants of growth and for the creators and producers of such technologies. They discussed the modeling of diffusion and explore the determinants of diffusion and the evidence for their importance.

### 2.5.1 Need of technology adoption

It is evident that firms adopt a new technology when they believe that adoption will result in short term or long term payoff in higher profits. Another major strategic reason could be their interest in gaining experience with the new technology (Amoako-Gyampah and Maffei, 1989). Thus adoption of strategic technologies that enhance the competitiveness of the firm has become one of the most important responsibilities of manufacturing manager (Dimnik and Johnston, 1993).

The firms which are able to adopt a particular type of manufacturing technology, becomes quite comfortable in adopting the next level of innovations (Mansfield, 1993). While discussing the acceptance of new technologies by industrialized world, Kuhlmann (1987) identified a few factors related to adoption of new technologies. Determination of the technology-market structure with special reference to customer preferences, penetration, technology content and planning for establishing of production is necessary to foster early technology adoption (Akhilesh and Ravichandran, 1994).

The adoption of technologies which are merely intended to replace older technologies in an existing process, can stimulate a complex set of changes. Over time, these changes will force a new look at the ways organizations justify investment in new technologies; encourage close interaction between product and process engineers reinforcing the need for simultaneous design and engineering of products; and force a more process-oriented approach to technology adoption which capture costs, especially environmental costs, over the entire production supply chain (Greis, 1995).

### 2.5.2 Technology adoption models

A model for systematic information gathering and thereby reducing the uncertainty in adoption decision has been suggested by McCardle (1985). He suggested a model to quantify the uncertainty and indicated that when to stop the information gathering and made a decision for adoption of a new technology.
A different model for making decision regarding adoption of new technology whose economic value can be gauged directly with certainty, was proposed by Mamer and McCardle (1987). The uncertainty can be decreased in this model by sequentially gathering information, updating his prior beliefs, ideas and opinions in a Bayesian manner.

Inter-organizational transfer and adoption of technology is concerned more with the relative importance of a source of information and the timing of its use. The adopting process has been characterized in a five stage model: (i) awareness, (ii) interest (iii) evaluation (iv) trial and (v) adoption. As far as adoption of new technologies by subordinates in an organization is concerned, Leonard-Barton (1988) observed that managers do influence the adoption process, such influence is not equally dominating under all circumstances. Goodman and Griffith (1991) proposed a multidimensional structure of implementation system. The suggested system has five processes namely, socialization, commitment, reward allocation, feedback and redesign, and diffusion, which are conceptually interrelated to each other at least theoretically.

Small and Yasin (2003) used information obtained from the advanced manufacturing technology (AMT) literature to develop a conceptual framework that seeks to illustrate the impact of the management information systems (MIS) department on the different facets of AMT adoption. A detailed survey instrument was administered to a cross-section of manufacturing firms in the USA to collect the data required to test five hypotheses relating to the efficacy of their framework. The results of their study indicated that the proposed framework by them is particularly useful in explaining the role of MIS departments in firms that are attempting to integrate advanced process and information technologies.

2.5.3 Organizational characteristics for adoption

Munro and Noori (1988) examined the pull-push or integrated theory as it relates to management’s commitment to automate their manufacturing process. They used survey results to characterize the variables concerning push-pull theory. In an attempt to avoid the measurement limitations that plagued previous research efforts, their research has incorporated multiple measures of the motivating forces (push/pull) and innovations (automation). Their study further proposed a conceptual framework which deals with the factors influencing the decision to automate. The framework, among other things identified the variables influencing technology-push and need-pull.
Veloso and Roth (2001) analyzed how technology, market and policy issues conditioned the adoption of aluminum in the manufacturing of auto engine blocks in Brazil. Due to important weight savings, there is a clear tendency in the auto industry to change engine material from iron and steel to aluminum. This tendency has started in the triad market area, mostly because of scale issues, but the increasing global perspective of the industry is now leading to expansion of these practices into emerging areas such as South America. They used a methodology developed at MIT entitled Technical Cost Modeling to explore the key issues conditioning the adoption of this technology in Brazil and assess potential supplier strategies for this market. Their analysis identified scale of production and local policy conditions, in particular the tax structure and the interest rate, to be the key drivers of differences in component sourcing cost. Their study concluded that casting engine blocks in Brazil seemed viable for production volumes above 65,000 engines per year for foreign investors and 100,000 for local manufacturers.

Brandyberry (2003) examined the relationships between adoption of computer-aided design (CAD) and five organizational characteristics that are likely to affect the probability of a firm adopting an information technology. The organizational characteristics tested are bureaucratic control, internal communication, external communication, organizational innovation, and the firm's size. Results indicated that bureaucratic control, internal communication, and external communication do affect the likelihood of a firm adopting CAD but organizational innovation and organizational size do not. These results suggested there are differences and similarities between the organizational influences associated with classic adoption models developed with emerging technologies and the organizational influences associated with CAD adoption and possibly other mature information technologies.

Astebro (2003) proposed that sunk costs of learning together with the size of output over which these costs are spread, determine both the probability and depth of technology adoption. Depth of adoption described the extent to which firms exploit the advantages of the technology they have adopted. He used national survey data from 271 U.S. plants in 20 metalworking industries to find that plant size but not firm size primarily predicts the probability of Computer Aided Design (CAD) and Computer Numerically Controlled (CNC) adoption. Learning costs appear to be lumpy and occur in short spells tightly connected to the installation of new technology and determine both the probability and
depth of adoption. He argued that decisions on learning after adoption seemed considerably more idiosyncratic than the decision to adopt.

### 2.5.4 Determinants for technology adoption

Siegel *et al.* (1997) examined the issues of adoption of advanced manufacturing technology (AMT) and changes in the composition of the labor force in favor of workers with higher skill levels leading to enactment of employee development and empowerment strategies to promote these changes; using a comprehensive, firm-level survey of technology adoption and human resource management strategies. Their findings indicated that AMT adoption is associated with an overall downsizing of the firm and a shift in labor composition in favor of workers with higher skill levels. They also suggested that “skill upgrading” of the workforce occurs after new technologies are implemented on the factory floor. They also found that human resource strategies that accompany these changes vary by category of technology adoption. Linked AMT appeared to be associated with a greater emphasis on employee empowerment. Conversely, compositional shifts toward managerial, technical, and R&D personnel are greater for integrated AMT. Slowikowski and Jarratt (1997) researched the impact of culture on the adoption of innovation. In an exploratory study, research was conducted with migrants from Vietnam and Poland to examine the impact of culture on the adoption of high technology products. Specifically, data were examined for differences in adoption of these products between Vietnamese and Polish migrants to Australia; and the effect of cultural factors, specifically, traditions, religion and fatality (beliefs about man’s inability to control nature), on adoption. Results indicated that culture has an important role in the adoption process of high technology products.

Swan *et al.* (1999) have compared adoption and design of collaborative computer-aided technologies for operations management within manufacturing firms in Sweden and the UK, and examined the influence of technology suppliers and professional associations in shaping these processes. These revealed differences in diffusion with earlier adoption of standardized packages in the UK and a stronger reliance on customized systems in Sweden. Tightly codified ‘best practice’ solutions have been pushed more strongly both by technology suppliers and also via professional association networks in the UK than in Sweden. This may have generated problems for UK firms because notions of ‘best practice’ under-emphasize the context sensitivity of the technology and the need for organizational redesign.
Small and Yasin (2000) argued that some researchers have found that unionized firms are less likely to pursue automation because high wage demands deprive them of the necessary capital required to invest in advanced manufacturing technology (AMT). Their exploratory study examined the relationships between firm-level union status and the adoption and performance of AMT in the discrete parts durable-goods manufacturing industry. Analyses of their sample, which included Chi-square tests, t-tests, correlation analyses and multiple linear regression analyses, revealed a union effect on the adoption of just-in-time technology and a moderately positive union effect on performance. They have discussed the results of analyses of the impact of union status, firm size and several human factor variables on firm performance.

Bennett and Vaidya (2002) addressed the question of how enterprises can improve their competitiveness through the acquisition and development of technology, and hence how countries became able to raise the level of industrial development and grow their GDP. They took the example of East Asia to demonstrate how fast economic growth can be achieved through the "stages" approach to technology acquisition and development. They also provided some case studies of technology transfer to China as a means of illustrating how successful transfer can be achieved and the problems that can be encountered.

Parhi (2003) has investigated the impact of geography on the adoption of AMTs in the less developed country context. Taking the Indian auto-component industry as a case for empirical investigation, she showed that being close to customers and machinery suppliers is strongly correlated with a higher rate of adoption of advanced manufacturing techniques.

Faria et al. (2003) investigated the main determinants of the adoption of flexible production technologies (FPTs), using a plant-level dataset of Portuguese manufacturing industry. In order to examine the effect of demand uncertainty, they estimated several econometric models for count data. These models dealt with the discrete nature of the dependent variable and firm specific unobservable characteristics arising from the cross-section context. They found that rank effects and technological regimes are important determinants of technology adoption, as put forward in previous models of technology diffusion; demand uncertainty has a significant positive impact on the likelihood of adopting FPTs.

Giunta and Trivieri (2004) conducted a study aimed at identifying the determinants of Information Technology adoption by small and medium sized Italian manufacturing firms.
(<100 employees). An ordered profit analysis is conducted on a sample of about 17,000 firms surveyed by the Italian Statistical Institute (ISTAT), using as a dependent variable an index of IT adoption called ITA. Their results showed that firm size, geographical location, functional composition of the workforce, R&D activity, subcontracting, exports and collaboration between firms are all highly significant determinants of IT adoption.

Maheshwari and Ahlstrom (2004) argued that past research on firm turnaround shows that the tendency of an organization to undertake a successful turnaround depends on a complex interaction between action choices in the organization and constraints in the business environment. Their case study extended this line of research by examining corporate decline and turnaround in an environment with numerous challenging environmental constraints: the state-owned sector in India. Using an in-depth case study of a state-owned enterprise in India, their research found that the business environment, the firm’s decision-making process, its leadership characteristics, and the stakeholders’ responses were all found to influence the firm’s action choices and turnaround process. Their study also showed that in addition to the strategic and operational changes so commonly associated with turnaround of firm, the importance of leadership and the basic credibility of the firm’s top management with major stakeholders and government officials also play key roles in it.

Kaushalesh Lal (2005) identified and analyzed the factors that influenced the adoption of new technologies in SMEs. Information and communication technologies (ICTs) have been used as a proxy of new technologies. The findings of the study suggested that industry-specific characteristics such as skill- and export-intensiveness have bearings on the type of ICT adoption. The size of operation measured in terms of sales turnover influenced the adoption of new technologies. The results also suggested that there are marginal differences in the labour productivity and profitability of firms that adopted varying degree of ICTs.

Chen (2005) analyzed the determinants of the levels and rates of technology adoption for petroleum refineries that survived the period during which the conditions of product demand and crude oil supply changed significantly. It is evident that firms adopt a new technology when they believe that adoption will have a short term or long term payoff in higher profits. Another major strategic reason can be their interest in gaining experience with the new technology.
Lefebvre et al. (2006) investigated the relationship between intangible assets and further advanced manufacturing technology (AMT) adoption in 116 small manufacturing firms. The results of their investigation indicated that the technical skills of blue-collar workers, the influence of customers and vendors, and strategic motivations focused on process improvement and customers are the strongest determinants of subsequent levels of adoption. Further, they showed that strategic motivations moderate the relationships between technical skills and influences and further AMT adoption.

Modi and Mabert (2007) presented a conceptual model of an organization’s efforts to improve supplier performance in a dynamic business environment. Then latent variable structural equation modeling was used to test the model. The results suggested that evaluation and certification efforts were the most important supplier development prerequisites before undertaking operational knowledge transfer activities such as site visits and supplier training. Further, collaborative inter-organizational communication was identified as important supporting factor in transforming an organization’s efforts to develop suppliers into supplier performance improvements.

Yin and Hu (2007) studied a general dynamic duopoly in which two firms compete in the adoption of current technology with a further new technology anticipated. Three kinds of equilibriums may occur in technology adoption, namely the preemptive, sequential, and simultaneous equilibrium, depending on the level of operating costs and the first-move advantage. It showed that the faster technological innovation encouraged the leader to invest earlier, while induced the follower to invest later.

Fallan (2008) presented a case study of the design and development of a Norwegian crockery series for institutional households. He investigated how this product represented a decisive break with the conventions of postwar Norwegian design and manufacture. He also analyzed how the manufacturer sought to portray this product. The translations of technology, design, identity and consumption showed how an artifact is constantly in a state of transformation.

Asakawa and Som (2008) compared and contrasted what the conventional wisdom suggested regarding the extent of opportunities and challenges of managing R&D as different in China and India from those in the West, and what the realities are in China and India, by drawing on academic literature as well as press articles. They suggested that multinational corporations (MNCs) should not forget the conventional wisdom of
managing their innovative R&D policies but should also learn from the unique challenges and capabilities in China and India.

### 2.5.5 Role of governments in technology adoption

Arvanitis and Hollenstein (1997) evaluated with some methodological considerations, the promotion of AMT by the Swiss government using micro-level survey data. They described a procedure for analyzing the impact of public promotion of AMT on the diffusion of such technologies, based on the estimation of an adoption equation within the framework of diffusion theory by using (primarily qualitative) firm data. Their approach took account of interaction effects between the policy instruments and factors determining the adoption of AMT, as well as the possibility of a reversal of causality between promotion and adoption. Their approach, although conceptually superior to most evaluation work in Switzerland, exhibited several shortcomings at the empirical level, reflecting to a large extent data deficiencies. Moreover, it did not account sufficiently for “soft factors” relevant to the adoption of AMT (e.g. the organizational environment).

Sohal and Maguire (1996) discussed the purpose, pattern and outcomes of investments in advanced manufacturing technologies (AMTs) in New Zealand firms. Based on data collected from 57 firms, they explored the motivation for investing in AMTs, the nature and size of investments, speed of implementation and outcomes including benefits and difficulties experienced. They concluded that although New Zealand firms have made positive investments in a range of sophisticated AMTs, they appeared to focus on operational benefits with little, if any, attention to marketing and strategic benefits.

Goel and Rich (1997) investigated the incentives of private firms to adopt new technologies. They performed econometric investigation on a pooled sample of individual US airline firms over the period 1971 to 1986. They found that firms subject to increased product market competition exhibit a higher propensity to adopt technological innovations.

### 2.5.6 Timing of technology adoption

Scarso (1996) dealt with the issues related to timing the adoption of a new technology. This was a very important question of strategy which directly affects the firm’s competitive capability and whose analysis cannot be adequately faced by conventional capital budgeting techniques. It aims to provide a procedure for deciding on the appropriate adoption time, which is based on the option pricing approach. In particular,
since innovative technologies generally disclose a set of strategic opportunities, makes the
assumption that adoption occurs when it is possible to profit better from these
opportunities. The decision procedure introduced also provides the starting point for
developing a practical, option-based framework to formulate a technology strategy. In
this perspective, he has proposed a proactive attitude of firms towards the planning and
looking for future technology opportunities.

Klenow (1998) modeled a firm’s decision of when to update its technology on evidence
that productivity growth from learning by doing diminishes as experience accumulates
with a technology; and learning by doing is largely specific to each production
technology. His model also implied that technology updates are more likely in a boom
than in a recession since a high rate of production enables the firm to learn more quickly
about new technologies. The forces in this model helped explain some features of plant
and industry level data, such as the procyclicality of investment including plant
investment spikes and the modest correlation between labor input and productivity.

Baldwin and Rafiquzzaman (1998) examined the determinants of the adoption lag for
advanced technologies in the Canadian manufacturing sector. They used plant-level data
collected on the length of the adoption lag (the time between a firm’s first becoming
aware of a new technology and its adoption of the technology) to examine the extent to
which the adoption lag is a function of the benefits and costs associated with technology
adoption as well as certain plant characteristics that are proxies for a plant’s receptor
capabilities. Economic theory suggests that the diffusion of advanced technologies should
be a function of the benefits associated with the adoption of new technologies. They made
use of more direct evidence collected from the 1993 Survey of Innovation and Advanced
Technology concerning firms’ own evaluations of the benefits and costs of adoption
along with measures of overall technological competency. Both were found to be highly
significant determinants of the adoption lag. Geographical nearness of suppliers decreases
the adoption lag. Variables that have been previously used to proxy the benefits
associated with technology adoption—variables such as larger firm size, younger age, and
more diversification by the parent firm also decrease the adoption lag—but they have
much less effect than the direct measure of benefits and firm competency.

Liu and Li (2003) employed option games approach to present a simplified duopoly
continuous time model of technology adoption. In the model, the irreversible investment
in adoption of the existing new technology is in strategic competitive circumstances and
facing the threat of a further new technology after the competition setting is established. Their results showed that rapid displacement of the technology encourages the leader’s investment and discourages the follower’s investment. Comparing with the optimal timing without the expectation of a further new technology, the firm hastens to invest when no firm has invested; however, once one firm has invested first, the firm will delay its investment. Using mixed strategy analysis, they derived competitive investment strategies with sequential exercise and simultaneous exercise.

2.5.7 Adoption: measurement issues
Thakur and Jain (2007) explored the issues of measurement and comparison of the current state of advanced manufacturing technology (AMT) adoption in India, including important information technology (IT) factors, and, surprisingly, this appears to be the first such attempt. For a worldwide perspective, comparison is made between Indian firms, firms in a developed country (Canada), and in a less developed country (China). Contrary to expectation, the average score of AMT adoption degree of Indian companies in their survey was higher than that of all Canadian companies (when unadjusted for size) and of Chinese companies in one of the highly industrialized regions of China as measured in other surveys. This suggested considerable strength of the Indian manufacturing sector. This study found the top six AMTs currently adopted in India are plant certification, computer aided design, local area network, quality circle, MRP/ERP, and wide area network. Clearly four of these top six are directly in the IT area (CAD, LAN, WAN) or directly dependent on it (MRP/ERP systems), indicating a strong IT adoption rate as well as its underlying supportive role in the overall AMT adoption in India.

2.5.8 Barriers to technology adoption
Mole et al. (2001) presented preliminary findings from a European Social Fund project that explores barriers to small and medium enterprises (SMEs) adoption of new technologies. Their research set out to investigate the adoption and effective deployment of technology within electronic and engineering SMEs and its relationship to the firm’s strategy and culture. It reviewed the agricultural economics literature on technology adoption and considers whether these findings apply to SMEs in industrialized countries. They reported an in-depth national survey sent to 1000 SMEs within the engineering and electronic industries, which questioned the firms on their size, investment, organizational direction, their adoption of new techniques, and the barriers to their adoption. The method
enabled the research team to test the hypotheses concerning information and risk aversion and generalize findings. They analyzed the data using SPSS and multivariate regression analysis and found evidence to support the risk aversion and information hypotheses. Further, they found that SMEs are ‘pushed’ into adopting new process technologies. Firms adopt process technologies to ‘catch up’ with competitors.

In summary, the literature on technology adoption is vast. Select studies studying diverse facets of new technology adoption, such as a firm’s decision to adopt, determinants, organizational characteristics, timing, location, size and other factors in technology adoption, incentives and policies for adoption, competition and barriers to adoption, and benefits of adoption in competitiveness are included in the above section. Brief results of these studies, many from the developed countries and many from less developed ones, have been discussed above.

2.6 TECHNOLOGY ADAPTATION

Adaptation means to carry out unaided technological design and redesign of the acquired technology. At this level of rooting, the firm is capable of going beyond mere imitation and is able to customize the technology to fulfill needs that it was not originally intended to serve. This requires a keen comprehension of the development theory underlying the technology, its interdependencies with other technologies, and the associated links to strategy (Leonard-Barton, 1990). This deep level of knowledge enhances the adaptability and competitiveness of the firm in a changing environment. Not all technology acquisitions would reach this depth, and in some instances, organizations may have trouble mastering relatively simple operational skills (Steensma, 1996). Adaptation is commonly aimed at making the adopted processes and products more effective in a local environment. An organization can expect little from new technology in general – and imported technology in particular – without developing its capability to modify and improve new technology for domestic applications. Domestic R&D is an important prerequisite for the sound selection, efficient assimilation, and fruitful adaptation of adopted technologies. Adaptation is also an important notion in most theories of human well-being.

Walter’s (2000) study dealt with a successful technology transfer process aimed at developing the detail engineering required to set up an oil plant in Tierra del Fuego. Specifically, it analyzed the relationship between the parties involved throughout the
cooperation process by which French technological assistance was provided to Argentine engineers. The study of everyday communication among the participants showed that the “translation” required for a successful technology adaptation is achieved when: (a) each partner actually carries out according to contract the complementary tasks for which he is responsible – specific competence.; (b) each party has some basic skills in relation to the specific competences of his partners; in other words, when they share a common technical language which enables communication – generic competence.; and (c) participants “recognize” in both senses of the term their partners’ idiosyncratic work styles. This is when a relational, socio-cultural competence derived from and effective only with regard to the specific ongoing cooperation process, is developed. Teschl and Comim (2005) have revised the original critique of adaptive preferences and compared it with a more detailed analysis of adaptation. They argued that adaptation can be a positive as well as a negative phenomenon and that the adaptive preference critique had a particular narrow view on adaptation.

2.6.1 Adaptation versus cloning

Grant and Gregory (1997) in their analysis have defined a manufacturing process as any repetitive system for producing a product, including the people, equipment, material inputs, procedures and software in that system. An issue of importance in this strategic decision is whether the process should be transferred without modification (referred to hereafter as cloning), or adapted in some way for transfer. Cloning a manufacturing process can maintain commonality throughout a global network of operations, and avoid reengineering costs. Cloning, however, requires robustness to the recipient’s (the host) local conditions and may not allow the exploitation of benefits from local factors of production. The alternative is to adapt some aspect or aspects of the manufacturing process. Through adaptation, the transferor (the home) can take advantage of local characteristics and can facilitate the transfer process. There is a need for a systematic way of assessing a manufacturing process, to ascertain whether cloning at an international transplant is the optimum solution, or whether the benefits deriving from adaptation would outweigh the costs. Their analysis aimed to present a model classifying those factors influencing adaptation to improve fit with local conditions, and those influencing adaptation to facilitate the transfer process. Constructs have been defined which, through classifying these factors, have described a manufacturing process’s overall fitness for transfer. Their analysis concluded with suggestions of how such constructs will help
clarify the challenges faced by transfer practitioners. They have also then tested the usefulness of these constructs, and the utility of the factor classification, in a case study.

2.6.2 Need of technology adaptation
The adaptation is commonly aimed at making the adopted processes and products more effective in local environment. Transferred technology cannot be said to be fully absorbed, until the technology has been made indigenous and regenerative, through complete digestion and absorption. Only after such modification is the development of a new improved technology possible.

Stohr and Zhao (1997) have proposed a conceptual model for technology adaptation for business process automation that stressed both technology-organization fit and technology-process fit. The goal of their study was to develop a systematic approach that addressed the needs for the organization to be adaptive and for work to be flexible. The technology adaptation model they developed is useful for technology providers in the workflow management area and for business managers who wish to take advantage of the new work-related technologies. The ability to adapt in a rapidly changing and complex environment has become an increasingly important aspect of competitiveness. While firms are free to make their own choices on when, and if, to adopt specific production technologies, they do not individually determine the direction of technological advance. New technology is not necessarily the best strategic choice for the individual firm, but adaptation requires the ability to respond to changes in the terms of competition brought on by other firms' use of new technologies. The strategic use model as proposed by Sonntag (2003) offered a framework for analyzing current trends in the development and use of production technologies in the context of the relationship of manufacturing strategy to changes in both product market needs and the use of AMTs. Manufacturing strategy forms a critical link not only in firms' ability to adapt to change in their environments, but also in their ability to knowingly shape their futures. The model is a tool for firms to critically examine the possibilities for using new production technologies to competitive advantage.

Andries and Debackere (2007) have hypothesized and tested that adaptation is crucial for the performance (measured as survival) of these businesses, but that this effect is moderated by the (in)dependence of the new technology-based business and by the industry in which it is active. They tested the adaptation-performance hypothesis through a survival analysis of a sample of 117 independent new ventures and business units. Their
findings have suggested that adaptation is beneficial in less mature, capital intensive and high-velocity industries but not so in more mature, stable industries. Also, adaptation reduces failure rates in dependent business units as compared to independent ventures. Dangaych and Deshmukh (2004) have reported the findings of an exploratory survey on advanced manufacturing technologies (AMTs) administered in Indian small and medium enterprises (SMEs) of automobile, electronics, machinery, and process sectors. The objective of their survey was to assess the status of AMT, identify AMTs relevant to Indian SMEs, identify competitive priorities, AMT implementation criteria, and assess the degree of investment in AMTs. Responses from 122 companies were analyzed and presented. They have concluded that Indian SMEs are giving the highest priority to quality and the least priority to flexibility. Further, post-implementation evaluation and requirement analysis in AMT implementation have attracted least attention from Indian SMEs.

New ventures as well as new business units experience significant difficulties in finding a viable business model. They often need to adapt their initial business model due to the presence of uncertainty and ambiguity. Technology based companies are confronted with particularly high degrees of uncertainty and ambiguity.

2.6.3 Requirements of technology adaptation

Domestic R&D is a prerequisite for the sound selection, efficient assimilation, and fruitful adaptation of foreign technologies. Priority must be given to the sound and efficient utilization of available foreign technologies. The success or failure of technology transfer solely depends on the accumulated level of technology of a nation. The higher the technological level of the nation, the better judge the nation will be for the assessment and selection of proper technologies (Mansfield, 1988).

The technology selection should explicitly consider the technology content in order to facilitate appropriate technology adaptation in a firm. Productivity is another factor affecting the adaptation decisions but its weightage is not very significant (Madanmohan, 1994). A conceptual model for technology adaptation for business process automation that stresses both technology-organization fit and technology-process fit has been proposed by Stohr and Zhao (1997). They have developed a systematic approach that addresses the needs for the organization to be adaptive and for work to be flexible.

Raj et al. (2007) have reviewed the literature on flexible manufacturing systems (FMS) and focused on its implementation. Global competition, advancements in technology and
ever changing customers’ demand have made the manufacturing companies to realize the importance of FMS. These organizations are looking at FMS as a viable alternative to enhance their competitive edge. But, implementation of this universally accepted and challenging technology is not an easy task. They have reviewed a large number of articles and found that the existing literature lacks in providing a clear picture about the implementation of FMS. They have reviewed the work of various researchers and found that it is really a very difficult task for any organization to transform into FMS on the basis of existing research results. A wide gap exists between the proposed approaches/algorithms for the design of different components of FMS and complexities of real-life. Besides describing the gap in various issues related to FMS, some barriers, which inhibit the adaptation and implementation of FMS, have also been identified in their review.

Kim and Pae’s (2007) recent study has focused on the environmental and managerial factors associated with the successful utilization of new technologies. To this end, their suggested framework has examined the efforts put forth by the two parties involved (the firm buying and the firm supplying the new technology). They have used 112 matched data collected from the suppliers and buyers of the customer relationship management system in business-to-business markets. They found that the perceived turbulence of business environments stimulates adaptive efforts from both the supplying and buying firms, which may lead to a high level of utilization of new technologies for the buying firm.

Vicente (2008) has identified that the over-arching purpose of human factors engineering is to improve the quality of human life, but ergonomics has not been as successful as its professionals would like in effecting societal change, whether it be at the political or corporate level. He addressed this problem, first by identifying a set of general challenges to change, and second by reviewing three illustrative theories of the processes behind large-scale societal change. He argued that past research programs have largely unappreciated ‘design’ implications that human factors engineers can adopt to increase the likelihood of improving the fit between people and technology in the service of humankind.

2.6.4 Flexible adaptation: strategies and frameworks

Handley and Levis (2001) have designed a model composed of individual models of a five stage interacting decision maker using an object oriented design approach and implemented as a Colored Petri net, in order to evaluate the effectiveness of different
adaptation strategies on organizational performance. They have used the concept of entropy to calculate the total activity value, a surrogate for decision maker workload, based on the functional partition and the adaptation strategy being implemented. They monitored individual decision maker’s total activity, as overloaded decision makers constrain organizational performance. They conducted a virtual experiment, in which the organizations implementing local and global adaptation strategies were compared to a control organization with no adaptation. The level of tolerance of the organization, the workload limit based on the concept of the bounded rationality constraint, was used to determine when a decision maker was overloaded: the limiting effect of the workload on performance. The timeliness of the organization’s response was used in order to evaluate organizational output as a function of adaptation strategy.

Lee and Chen’s (2003) inductive research has attempted to explore the dynamics of firm internationalization process, with a focus on a manufacturing firm’s first-time foreign entry endeavor. By conducting comparative analyses based on six cases of Taiwanese manufacturing firms who have established production bases in Indonesia and Malaysia, they postulate a conceptual framework entailing relationships among entry decision, implementation strategy, and local adaptation. They highlighted the role that subsidiary’s entrepreneurial initiatives play in achieving required extent of local adaptation. Hence, successful implementation for companies lacking sufficient experiential knowledge of internationalization. They based their propositions on the conceptualization and discussed the implications of these qualitative insights, with an expectation of contributing to the extant theories of internationalization.

Tigre and Dedrick (2004) have presented an interesting case study of local factors influencing the adoption and impacts of e-commerce in Brazil. It is a large less developed country in which some segments of the economy are technologically sophisticated while others are quite backward. Based on existing knowledge of Brazil’s economic and policy environment and its experience with other information technologies, they have developed three themes that encompass a priori expectations about the diffusion and impacts of e-commerce. First is the expected leadership of the financial sector, driven by strong IT capabilities and a historical orientation toward automation. Next is the leadership of large firms in adopting e-commerce, driven by economies of scale and scope that enhance the perceived benefits of adoption. Third is the relative importance of local versus global forces in driving e-commerce diffusion. Unlike other countries in which globalization is a
driver of e-commerce diffusion, Brazil’s relatively low international integration of the manufacturing industry, its large size, and its historical inward orientation are expected to reduce the role of global factors as e-business drivers. In addition, they found that the lack of an adequate legal and regulatory environment to support e-commerce has been an important barrier to adoption.

Laosirihongthong and Dangayach (2005) have developed a conceptual framework for new manufacturing technology (NMT) implementation. Scales representing management activities within four stages (adoption, pre-implementation, implementation, and post-implementation evaluation) of the framework have been developed. They used data from the survey of 149 Thai automotive manufacturers to test for content validity and reliability of those scales. Then they applied factor analysis to validate and confirm the construction of the framework of each stage. The result of data analysis indicated four stages of NMT implementation, consisting of (a) determining reasons for NMT adoption, (b) monitoring and justifying whether a certain NMT should be adopted, (c) adapting an existing organizational culture while implementing proper project management approach, and (d) evaluating an effectiveness of NMT implementation.

Koh et al. (2005) proposed a new design knowledge expression method called design DNA is proposed in their study aimed at increasing the flexibility of the knowledge structure for accumulation and adaptation. For this, a non-hierarchical knowledge structure is needed. Design DNA facilitates the rearrangement of design knowledge, promotes the flexibility of knowledge structure, and evolves the creative knowledge from similar design. Design DNA is based on layout oriented domain knowledge and function-oriented domain knowledge, which enables generating new design knowledge resulting in new part geometries for given constraints on the part functions. Design DNA is applied to the design knowledge of passenger car parts as an example and shows systematic accumulation and various adaptations of design knowledge.

2.6.5 Role of governments in technology adaptation
Schulze-Cleven et al. (2007) have discussed the challenge for the advanced country is to stay wealthy in a rapidly evolving and ever more competitive global economy. As a new digital era emerges and the mechanisms of value creation – that is, the engines of productivity and growth – change in volatile marketplaces, wealthy nations have to find new ways to adapt. Particularly in Europe, successful adjustment has often been posed as a choice between social protection and market flexibility. In their study, they recast this
all too common framing and emphasis instead that competitive advantage for the advanced countries may be built through appropriate social policy. Upon clarifying the character of competition in the emerging digital era, they argue that the long-standing strong social protection systems in many European countries could be leveraged to these countries’ unique advantage in the emerging digital era. With such benefits as promoting social peace and assisting people in meeting new labour market demands, social protection systems have an important role to play in helping societies reorganize existing economic structures in support of successful adaptation to new competitive conditions. They situate the current dynamics and choices of the digital era by briefly tracing the evolution of historical production paradigms, highlighting for each the relationships between technology, business problems and the resulting domestic and international politics. Then they delineate a newly emerging digital production paradigm and elaborate the accompanying theory of value creation. Driven by the application of distinctive digital tools, firms’ internal functions increasingly become products to be bought in the market, products that generate premium prices are turned into commodities, and the sources of differentiation for products, services and their production processes evolve. They also reflected on the lessons of the Danish experience for other European countries’ attempts to meet the challenges of the digital era. Lessons about social protection are not only relevant not only for the ‘coordinated’ economies of Continental Europe, but they apply more widely, even to distinctly ‘liberal’ countries.

2.6.6 Adaptive learning

Bullnheimer et al. (1998) have studied the adaptive behavior of firms that repeatedly have to make a production decision. In a single good market, firms use own experience as well as information gathered by observing competitors to iteratively choose a production technology out of a given set. The adaptive learning of the firms is described in a dynamic model and analyzed in a simulation framework. They showed that a small but positive propensity to imitate is optimal for the firms and yields production efficiencies above 95% of the maximal value. Furthermore, they observed that in a competitive situation firms using optimal propensities to imitate outmatch pure imitators and non-imitators in production efficiency as well as in profits.

Rasiah and Ashish Kumar (2008) have examined differences in technological intensities between foreign and local automotive parts firms in India. Foreign firms enjoyed higher labour productivity, wages, and export, technological and skills intensities than local
firms. The econometric results showed a strong relationship between labour productivity and technological intensity. The technological intensity variable (including its components of human resource, process technology and R&D) was also strongly and positively correlated with skills intensity. Foreign ownership was only statistically significant and positive in the human resources regressions. Local firms also showed statistically significant levels of technological intensity (especially in process technology) when competing in export markets, suggesting that foreign firms may offer a competitive and complementary presence to spur local firms’ development.

2.6.7 Barriers to adaptation

Madanmohan (2000) has developed a theory aimed at understanding persistent difficulties with efforts at developing plant-level indigenous technology in a less developed country. He identified these major barriers to technology adaptation: (a) inappropriate choice of technology, (b) inadequate planning and support for innovation, and (c) inappropriate process reveal, and (d) product-market mismatch and inadequate market survey. Murillo-Luna et al. (2007) have analyzed the determinants of the strategic environmental behavior of firms and, more specifically, the external and internal barriers that limit and sometimes even prevent the environmental adaptation. Their analysis focused on a sample of industrial firms that have at least three workers and that are located in Aragón, a region situated in the northeast of Spain. From the firms which were sampled, they studied the existence of an underlying structure among the totality of barriers. Finally, they analyzed this structure in order to determine if it has any influence on the degree of proactivity of the firm’s environmental strategy.

The literature on technology adaptation covers diverse issues. Select studies and a literature review covering different facets of flexible management of new technology adaptation, such as adaptation needs, performance, flexibility, process, conditions, and factors; adaptation implementation frameworks; role of national policy in adaptation; local and foreign technology intensity; barriers to adaptation; benefits of adaptation; and adaptive learning are included in this section. Besides, many studies included discuss one or more issues of adaptation from one or two countries’ or sectors’ perspectives.
2.7 TECHNOLOGICAL CAPABILITY BUILDING

The research literature available on economics of technical change and innovativeness of firms to effect such changes in respect of developed countries is quite large. In the case of less developed countries, substantial literature has accrued on technology choice and transfer. Some recent surveys in these areas should be useful. However many researchers feel that mainstream economics has relatively neglected several related conceptual issues, the phenomenon of technical change and the associated capability (Freeman, 1994) and hence they are poorly understood (Bhalla et al. 1985, Fransman 1985). Broadly speaking, research studies on technological capabilities and change can be classified into two conceptual dimensions viz. developed countries - micro level issues, and macro level issues, less developed countries - micro level issues, and macro level issues. The research agenda in respect of less developed countries shifted from topics such as factor pricing, technology choice, and technology transfer to the real technological change-taking place in them.

The question that arises is 'why can't less developed countries use the considerable research literature that is available on developed countries to make policy that promote firm level technological capabilities (FTC's)? While a few researchers have suggested that the results of innovation studies on developed countries may offer some guidelines to policy making related to technological capability in less developed countries (Fransman 1985, Cooper 1991) many others disagree with the adequacy and appropriateness of such studies to the latter (Textile 1984, Kim and Dahlman 1992, Karagozoglu 1988). The reasons behind their disagreements are perhaps, due to some of the major differences between developed and less developed countries. The structure of industry makes rules of business. Individual income levels, life-style in less developed countries are characteristically different. A bulk of the technologies used in less developed countries are simple and mature because they either cannot have access to emerging technologies or they do not find it useful in their environment (Lee and Choi, 1988). While developed countries move from research to development, and then to engineering, less developed countries largely progress in the reverse direction. Developed countries are largely engaged in risk, skill, effort, and time intensive activities such as new product, process or application development. But, the technological activities of less developed countries, such as adaptation of acquired technologies to local requirements and making minor improvements, are relatively for less intensive in terms of the above-mentioned criteria.
Most developed countries have a sophisticated manufacturing base compared to that of less developed countries. These are adequately supported by sophisticated technological infrastructure in terms of the services related to engineering and construction, consistency, information systems, meteorological and base research facilities etc (Reddy and Zhao, 1990).

Measures or indicators of technological capabilities found in studies on developed countries are not appropriate in the context of less developed countries. In the wake of the differences between developed and less developed countries, and even among the latter, it is necessary to design research studies appropriate to local conditions (Page, 1994).

Several commonly used terms including "technology" "technological change"; "technological capability" and "innovation" are used with different connotations. The way these terms are understood and defined; influences the research designs and their results, policies, and business practices (Reddy and Zhao, 1990). It is very important that they should have some common grounding. In development literature, technological capability represents the abilities of productive enterprises to handle industrial technologies and cope with technological change (Lall 1993). Broadly, they can be referred to as those abilities of an organization, which enable it to undertake various technological activities (Sharif, 1986). Development of suitable indicators to measure technological capabilities enables conducting meaningful research and making policies. The technological capability indicators can broadly be classified as: a) input indicators, including R&D inputs, sophistication of production systems, and length of manufacturing experience; b) Output indicators, that include number of publications, patents, and innovations, production outputs, and exports, and c) a combination of input and output indicators such as measures of productivity. These indicators are largely unsuitable to use in the context of less developed countries due to their peculiar environment (Sharif, 1986).

Besides, capability studies in the context of developed countries have largely focused on "innovation capability" which constitutes only one of the elements of technological capabilities in less developed countries. There are several other elements of technological capabilities (those related to technological acquisition, implementation and utilization), that hold a great potential for development, which less developed countries can not afford to ignore (Lall, 1993). Hence blind acceptance of measures as given by the developed countries is open to questions. In fact, the measures in the case of less developed
countries should be for the whole range of firm level technological capabilities and not just one.

A bulk of technological capability literature available on less developed countries has focused on issues and factors at macro level (industry, spectral, national, regional or international level), while issues and factors affecting at micro level (firm level) is negligible and few integrative approaches to address the problem of FTC (Karagozoglu, 1988).

Lall (1992) has reviewed the implications for industrial strategy of research on technological capabilities at the firm and national levels. After exploring the nature and determinants of micro-level technological development, he has set out a simple framework for explaining the growth of national capabilities, based on the interplay of incentives, capabilities and institutions. He proposed that each may suffer market failure and so require corrective intervention. He has described the experience of some industrializing countries to assess the validity of this framework. He has concluded his review by saying that interventions, carefully and selectively applied, are necessary for industrial success.

Rasiah and Tamale (2004) have examined productivity, export-intensity, skills-intensity and technological differences between foreign and local firms in metal engineering, textile and garment, food and beverages plastics and other industrial firms in Uganda using the technological capability framework. In metal engineering, foreign firms enjoyed higher and statistically significant technology index, human resource, process technology and R&D capabilities than local firms. However, the remaining t-tests produced mixed results. Nonetheless, foreign firms enjoyed stronger statistical relationships between the technology index, and productivity and export-intensity, and export-intensity and skills intensity. Foreign firms also enjoyed a stronger statistical relationship between export-intensity, and technology index and human resource capabilities. Overall, the results suggest that local firms can learn considerably from the operations of foreign firms in Uganda.

Rasiah (2004) has also examined differences in technological capabilities between foreign and local auto parts, electronics, and textile and garment firms in Indonesia. Foreign firms enjoyed higher export incidence than local firms in all three industries. Foreign firms enjoyed higher overall technology and HR intensity means than local firms in auto parts and electronics. Foreign firms enjoyed higher and statistically significant process
technology mean than local firms in electronics. Foreign firms also enjoyed higher means than local firms in process technology and R&D intensities. The econometric results showed a strong relationship between export-incidence, and overall technological, HR and process technology intensities. Foreign ownership was not only statistically significant and its coefficient positive in the overall sample of the HR regression, but it also emerged that export-incidence was stronger among foreign firms. Export-incidence involving process technology regression was also stronger in the foreign firms' samples.

2.7.1 Technological capabilities for competitiveness

Viana and Cervilla (1999) have studied the technological and competitive capabilities of the Venezuelan manufacturing firms based on a model of managerial dynamics. Their model takes into account a group of variables related to the strategy of the firms as well as variables related to techno-managerial and innovation capabilities. The data gathered was statistically processed by means of factor analysis and hierarchical cluster analysis. The result was a series of indicators of variables related to the strategy of the firm, as well as variables related to techno-managerial and innovation capabilities. A global competitiveness index was constructed in order to locate and to compare firms (and groups of firms and sectors) according to their technological and managerial capabilities. This “competitiveness index” was formed by the three indexes: Capacity (i.e. the managerial and technological capabilities), Innovation (i.e. the change related activities) and Strategy (i.e. the main strategies of the firm). Their results made a reflection about the strengths and weaknesses of the firms in a sector, in order to formulate managerial strategies and industrial policies directed to improve the competitiveness, so that they can face with success the enormous challenges outlined in a new environment characterized by quick technological changes and globalization.

Rocha (1997) has provided evidence on the role played by firms’ technological competencies in the determination of their intensity of cooperation with other firms. Using a database composed by patents jointly filed by two or more firms in the European Patent Office, the study found no support for the hypothesis that in order for firms to increase their rate of cooperation they should expand their R&D expenditures; held that technological cooperation is explained by the need of the firm to acquire complementary competencies; concluded that cooperation is an alternative technological strategy for those firms that have adopted lean production to overcome obstacles posed by the cross-fertilization of technological fields; and showed that Japanese firms have a higher level of
cooperation than Western ones. This latter feature may be explained by greater level of productive specialization of Japanese firms.

Battisti and Pietrobelli (2000) have developed a theoretical framework to analyze intra-industry gaps in technology and have tested it with enterprise-level data from a developing country, Chile. Their analysis focused on five major sectors: food processing, textile and garments, woodworking, metalworking, and paper. They found that firms with different levels of technological complexity co-exist within the same industry, and differences in technology are discrete, with different clusters having similar characteristics within the same industry.

Kim (2000) presented an analytical framework on how industrialization takes place through the development of technological capability in interactions with the evolution of market competition, government policy, corporate strategy, and social culture in the context of less developed countries. This framework is applied to Korea to describe the dynamics of technological learning in the industrialization process. The Korean experience suggests a set of implications for other less developed countries, such as, export promotion as an effective policy instrument for creating competitive stimulus for firms to expedite technological learning; expanding and improving quality of education as a basic government measure for helping firms build an adequate existing knowledge base; a liberal policy on brain drain in the early stage of industrialization can benefit less developed countries in the long run; a high tacit knowledge base is a prerequisite to effective technological learning; technology transfer should evolve over time, as industrialization progresses; intensity of effort as another prerequisite for building technological capabilities for industrialization; public technology policies should evolve over time to respond to changes in market and technology environment; and the role of government research institutes should evolve over time.

Wignaraja (2001, 2002) has explored the role played by internal technological factors on the exporting behavior of enterprises of different size classes in the Mauritian garment industry by constructing a technology index and conducting econometric analysis on factors affecting enterprise-level technological development and export performance in a sample of Mauritian garment enterprises. The econometric result showed that firm size, technical manpower, training expenditures and external technical assistance are positively related to the technology index. This confirmed that investments in human capital and seeking information, both facilitated by size, improve technological performance. This
was strengthened by the fact that the technology index and foreign ownership have positive and statistically significant effects on export performance of each firm. The mathematical model of technology index was found to be a robust tool of empirical research and can be used to analyze the technological record of enterprises in adjusting less developed countries.

Chandra and Sastry (2002) have presented findings of the second national survey on the competitiveness of Indian manufacturing. They have developed hypotheses on the competitiveness of firms in the manufacturing sector and addressed some key questions on the characteristics of world class firms in India. They have also analyzed the processes and practices that such firms have adopted to become world class. More important, they have highlighted firm level practices that are preventing Indian firms from becoming globally competitive. Their findings point towards three distinct aspects of manufacturing management that define the capabilities of the firm, i.e., strategies related to dynamic control of shop floors, network linkages and innovation. They have found that those firms that build distinctive technological and managerial capabilities in these domains are able to compete globally. They have provided a comparison with manufacturing capabilities of competitors in China and drawn lessons for organizing large scale manufacturing. They have also provided an assessment of the changes that have happened in manufacturing priorities and strategies in India since their last survey conducted in 1997 and highlighted the implications of these changes.

Kumar and Jain (2003) have presented findings of field research to study the status of new technology commercialization practices in India. Their focus was on the parameters that influence the decision regarding commercialization of new technologies and the success of new technology ventures, the efficacy of existing financing/support mechanisms and the further actions required by stakeholder agencies, viz., industry, technology institutions, financial institutions and the government for further development of commercialization of new technologies in India.

Viljamaa (2007) has examined the emergence of university–industry partnerships in the motor sports industry cluster located in the Charlotte region of North Carolina, USA. Despite little industry demand for the local engagement, the universities and community colleges started to approach the industry in the late 1990s and recently several new programmes of motor sports-related research and education have been initiated. During last few years, the regional and state governments have also started to play a role in
building up support for the motor sports industry. This process has largely been influenced by the ideas of knowledge economy and innovation as an interactive process, by the ideas of the wider social and economic role of universities, and by increase awareness of the relevance of the motor sports industry for the regional economy. Charlotte’s motor sports industry is an interesting example of how a previously rather craft-based industry transforms into one in which technology, innovation and creativity play a key role in firm performance. However, the strategy for building up regional capabilities and relationships necessary to support the increased technological intensity of the industry has been slow to develop. He addressed the important question of how the universities together with other research and educational organizations can build collaboration with an industry that has traditionally prospered in the region without any links to them, but which in the face of technological challenges needs to reach out to access cutting-edge knowledge and highly qualified personnel.

Swink et al. (2007) have focused on the integration of strategic objectives and process knowledge that a manufacturing factory collects from its external interfaces. Using data from a variety of manufacturing industries, their study examines four different types of strategic integration at the manufacturing plant level. They used a path analytic approach to simultaneously assess the contributions of the various types of integration to manufacturing-based competitive capabilities and business level performance. In addition, they have examined the intervening roles that manufacturing-based competitive capabilities play in mediating the relationships between strategic integration and business performance. They found that each type of integration activity has unique benefits and detriments. These findings extend prior studies of manufacturing and supply chain integration by broadening the theory relating to strategic integration. Their results also provide implications for manufacturing managers who seek to design integration policies and associated resource deployments.

2.7.2 Measuring technological capabilities

Hobday (2002) has developed a framework for technology needs assessment (TNA) to identify technology needs and priorities of less developed countries in order to ensure successful technology transfer. He has developed the framework from a local capability point of view of less developed countries. He has covered both dimensions of technological capability viz: (a) the capability to develop strategies and manage technological acquisition, use, and further development; and (b) the detailed engineering
capacity needed to acquire and develop specific technologies. H has recognizes the first dimension as the most important and has offered a framework and specific tools for technology analysis needs of less developed countries.

Three versions of TNA have been developed by him: at national level, at sector level, and at the enterprise level. TNA at firm or enterprise level has been discussed in detail in the 2001 CAPTECH Manual (Bessant et al. 2000). To complement the CAPTECH Manual, Hobday has developed a Self-Assessment Technological Capability Audit Tool. Using this audit tool, a firm can first calculate its overall technology capability level, and secondly identify detailed strengths and weaknesses according to nine sub-categories of technology capacity. There are 24 questions in the audit tool and responses are analyzed on a four point scale.

2.7.3 Building technological capabilities

Wei (2000) has examined the questions of (a) how in a rural zone, has indigenous technological capability been acquired, and (b) what role is played by municipal governments in the process, and (c) what kinds of policies were helpful in fostering acquisition of technological capability in special economic zones (SEZs). He concludes that economic growth does not necessarily lead to structural transformation in SEZ. These zones contribute to, and are in turn affected by, the process of development within a country.

Aminullah (2000) has attempted to understand the structure underlining the weakness of the Indonesian economic development strategy in a systemic perspective. The explanation assumes the importance of industrial technological capability within the framework of the techno-economic structure. The results of a simulated model of techno-economic administration show the weakness of the industrial technological capability. This is a determinant factor of low industrial efficiency that brings about the current discontinuity in economic progress. On the basis of policy simulation, there are techno-economic policy initiatives needed to strengthen the future industrial technological capability. It implies that there is a need to shift from economic towards techno-economic policy orientations. Failure to confront this policy issue will make a new cycle of economic crisis possible.

Jiang (2000) has analyzed firm’s technological capability enhancement in highly competitive and demanding business environment as a strategic planning. The technological capability, which refers to the firm’s knowledge and capacity embedded
into the individual and organizational resources, is one of the most important potentials for firms to gain the sustainable competitive advantage and high benefit return. With the enhancement of technological capability, the firms gain the sustainable economic rectum in the long time. First, they have proposed the implicit logic between the technological capability enhancement and the growth of benefit return. Second, the paper discussed the accumulative rule of the firm’s technological capability from four dimensions: humanware, orgaware, technoware and inforware. It adopted the economic cybernetic model to explore the interactive functions between the technological accumulation and economic return. Third, it used the case of Hangzhou Machine Tool Company to analyze the economic perspective of technological capability improvement.

Oner et al. (2003) have assessed technology management capabilities and draw capability profiles of firms in automotive, white goods and electronics industries in Turkey. Using a capability assessment process model entitled ‘TPMCPM’, their study diagnoses the actual source of deficiency in management of technology processes and makes recommendations for enhancement of the technology-related practices.

Techakanont (2002) investigated the process of inter-firm technology transfer (TT) in Thai automobile industry in his doctoral dissertation and concluded that once a firm decides to invest in, it not only has to carry out the process of intra-firm TT, but also of inter-firm TT to another country. Techakanonta and Terudomthamb (2004) have further investigated the evolution of ‘inter-firm’ technology transfer in the Thai automobile industry, which has gradually been integrated into global production network of some specific automotive models (one-ton pickups). They have discussed the linkage between the role of automobile assemblers in transferring technology and the way their strategic changes bring about heightened demands on the technological capacity of suppliers and the contents of technology transfer. With higher competition at the global level, local suppliers are required to improve their technical and managerial skills, especially in the area of ‘product engineering’ capability. They have examined the ways local firms have adapted to these changes in their environments, as well as the ways they utilize inter-firm relationship with automobile assemblers as a means to improve their own technological capabilities. They have also discussed dynamic process of capability formation in local parts firms, through intensive efforts and learning inducements brought about by inter-firm relationships.
Gammeltoft (2004) has reported from a broader study of development of technological capability in the Indonesian electronics industry with particular focus on local companies. He has discussed the concept of ‘technological capability’, proposed operationalization of the concept, devised a model of capability development at the firm level. An empirical survey of the industry was carried out on these bases. The Indonesian electronics industry is conventionally depicted as being ‘dual’ but this study establishes that not just two but a larger number of qualitatively different industrial segments should be recognized. Capabilities and the ways capabilities are developed are analysed for companies belonging to these different segments. He found that local companies in several respects come out as more technologically capable than usually assumed.

Yu et al. (2004) try to explore the technological capability development process by latecomer firms, especially those in big emerging countries. Based on the insights summarized from the case study of China’s telecommunications manufacturing sector, they have shown how the latecomer firms can penetrate the technical cycle and gradually cultivate their own technological capability in the local market. Four continuous inter-linked capability building strategic processes, namely: core acquisition, gap identification, specific exploration, and quick provision have been mapped discussing various activities involved in each of these processes. This process model has the advantages to integrate strategic process thinking and actual operations of the latecomer firms facing the global competition. Finally, they have proposed a research program to test the model.

Oyelaran-Oyeyinka and Lal (2004) have examined through field data, the ways in which medium and small enterprises in selected less developed countries learn to use and augment their core capabilities with new technologies. They presented three findings. First, there was clear evidence of increasing complexity in the adoption and use of ICTs among firms in less developed countries. Second, climbing the technological ladder required skills upgrading through explicit learning of the new technologies. Third, firm performance was highly associated with learning capabilities, levels of technology, and a host of firm-level knowledge, skills and experience. Their study formed that across countries and sectors, non-formal learning is the dominant form of mastering new technologies. However, formal local and overseas training are positively associated with increasing technological complexity. There is also a close correlation between technical complexity of firms' internal ICT tools and available telecommunication infrastructure.
Raghavendra and BalaSubrahmanya (2005) have explored the influence of various learning mechanisms on the acquisition of technological capability in small industry clusters through a field study conducted in two foundry clusters in south India. They probed whether the collective efficiency through higher inter-firm linkages and cooperation with firms/agencies within a cluster as well as outside the cluster, lead to higher technological capability. Seven variables affecting technology capability building were employed in the study, namely: age of the firm, education of owner/manager; working experience, horizontal collaboration, vertical collaboration, mobility of skilled labour, and external technological assistance and information flow. They developed suitable proxies to measure technological capability and the learning mechanisms, thus facilitating quantitative analyses. The evidence suggests that collective efficiency, either in the form of horizontal cooperation or vertical cooperation, has a significant influence on technological capability. However, it is the factors like proximity to markets, nature of the cluster – homogeneous or heterogeneous, that appear to reinforce the kind of cooperative efforts, horizontal or vertical, that are more conducive to the acquisition of technological capability in firms.

Daniels (2005) has systematically identified conditions in lower income countries (LICs) that would likely promote, and benefit from, the pervasive adoption of material- and energy-saving technologies. He has explored empirical link between technology capability and human development index. He concluded that a green socioeconomic paradigm may well provide a viable alternate approach in the LICs. He has suggested that the main advantages of this are derived from related resource efficiency gains and reductions in socioeconomic metabolism, and the benefits of a relative production factor shift toward labour and away from materials, energy and environment-intensive capital.

Sherifaw (2007) has examined the entry, survival and exit patterns of Ethiopian manufacturing firms using census-based panel data for the period 1996 to 2002. His study revealed an underlying market selection mechanism that reallocates resources towards more efficient producers and forces inefficient firms to close down. This process also contributed to aggregate productivity growth although the manufacturing sector continued to lose productivity due to intra-firm productivity decline. He also explored the accumulation of technological capabilities and their role in firm-level productivity growth. Data from a sample survey showed a very sparse incidence of innovative activities in Ethiopian manufacturing. Nonetheless, firms that engage in building
technical capabilities exhibit higher levels of productivity after controlling for other firm characteristics. He concluded that while markets contribute to aggregate productivity growth by exerting competitive selection, long-term industrial competitiveness in less developed countries could be stifled because of inadequate technological learning.

2.7.4 Role of governments in building technological capabilities
Caloghirou et al. (2000) have examined the process of technology transfer and associated learning effects experienced by the Greek telecommunication equipment manufacturer Intrakom as a result of its involvement in public procurement processes and the technological shift towards software-driven digital switching and transmission systems. Drawing upon the role of Government procurement as an instrument for industrial policy and the learning potential of a technology transfer process, they argued that the Public sector's industrial policy considerations, exercised through the procurement practices of the Greek Public Telecommunication Operator, as well as Intrakom's own timely focus in establishing a long-term collaboration agreement with a leading international vendor Ericsson played a catalytic role in the accumulation of domestic capabilities in the manufacturing of selected telecommunication equipment products.

Huq (2004) has made an attempt made to highlight the case for explicit, coherent and effective technology policy as the way forward in rapidly globalizing economies, especially those in the developing world. In this regard, his paper invokes some recently published evidence from three countries of the Indian subcontinent, namely Bangladesh, India and Nepal, all of which are low-income developing countries. He concluded that technology policy is destined to promote enterprise culture, R&D and innovation initiatives would ultimately enable developing countries to produce global competitive players in various areas of economic activity. On the other hand, he argued that the failure of government policy to address local problems in the context of developments in the wider global economy will see low-income countries locked into vicious circle of poverty.

Intarakumnerd and Virasa (2004) have focused on the significant issues of technological capability development of latecomer firms, and government policies enabling such firms to attain certain level of technological capability. They surveyed and conducted case studies of manufacturing firms in Thailand to substantiate and investigate the process of technological capability development of latecomer firms. Their analysis portrayed a dynamic view of technological capability development that comprises three key elements
namely strategic capability, internal capability, and external linkage capability, reported as a “Development Staircase” of a firm’s technological capability. They subsequently, discussed and suggested a tentative taxonomy of government policies and measures to support firms’ technological capability development through the development staircase.

Sadoi (2008) has examined the process of technology transfer from foreign to local firms in the automotive parts industry in China, focusing on parts localization processes and technical capabilities. Using survey and case study information, his study compares parts localization and technical transfer programmes in China with the experience of Malaysia’s Proton. The results show that Chinese firms have achieved localization much faster than Malaysia’s Proton largely due to the strategic nature of government policy on foreign direct investment (FDI) and technology transfer.


2.8 LIMITATIONS OF EXISTING APPROACHES

It is very surprising to learn from the literature, that not much has been written about the management of technology adoption and adaptation for building technological capabilities in less developed countries (as compared to developed countries) in general and India in particular. After the liberalization of Indian economy and globalization of trade, commerce, and industry, being initiated in 1991, there had been a rush for technology transfers from developed countries. Indian management researchers have started penning down the things but only in a very limited domain. There have been some stray cases available of technology transfer in the literature which do not reflect fully the motives behind adoption of technology from abroad, and the subsequent experiences in developing technological capabilities. There has been a lot of research done on technology adoption, technology adaptation or building technological capabilities independently, but the research regarding the linkages between these is missing. So this
research has been planned to develop a conceptual framework to build technological capabilities through flexible management of technology adoption and adaptation.

A comprehensive attempt has been planned for analyzing the cases of technology adoption and adaptation for building technological capabilities in manufacturing firms for a large country such as India.

2.9 CONCLUDING REMARKS

A selective review of available literature in the field brings out a few points relating to management of new technology in a logical manner. These include lack of understanding of what to expect and what not to expect from technology adoption and adaptation, role of flexibility in technology adoption and adaptation, and the knowledge of technological capability building for a given organization.

This review is an attempt in this direction in the Indian context to cover a few of these points, particularly those relating to organizational and managerial issues of managing new technology adoption and adaptation for building technological capabilities in manufacturing industry in a flexible way. Based on the literature reviewed above, a few important factors concerning technology adoption and adaptation have been identified. A conceptual framework representing the cyclic process of building technological capabilities through flexible management of technology adoption and adaptation has been derived using factors identified in the literature. In this framework, the technological capability building in a firm process starts from technology adoption. Technology adaptation is the next stage in this cyclic process. Facilitated by technology adoption and adaptation, a firm develops its technological capabilities, and this completes one cycle. By virtue of acquired technological capabilities, the firm then proceeds for adoption of next level of technology, after the adaptation of which, technological capabilities of the company are further developed and the cycle continues. Graphical representation of this process is shown in Chapter 6 (figure 6.4). The factors identified were also taken into account for carrying out empirical study and analysis, and for case studies.